Wind Energy Forecasting

Marc Schwartz

FY2005 DOE Wind Program R&D Implementation Meeting

November 18, 2004

Major Issues

- Problem- Accurate forecasts are required to mitigate certain concerns
  - Utility integration
  - Ancillary costs
- Forecast objective- Enable clients to make proper decisions
- Successes
  - Example of working with private industry to develop new market niches
  - Forecasting is commercially viable and growing
  - Established relationship with NOAA/Forecast Systems Laboratory

U.S. Commercial Wind Energy Forecasting Firms

- Companies either forecasting for clients or have expressed interest in forecasting
  - AWS Truewind
  - 3 Tier Environmental
  - WindLogics
  - WSI
  - RESPR
  - AMI Environmental
- List is not all inclusive

Past Forecasting Work

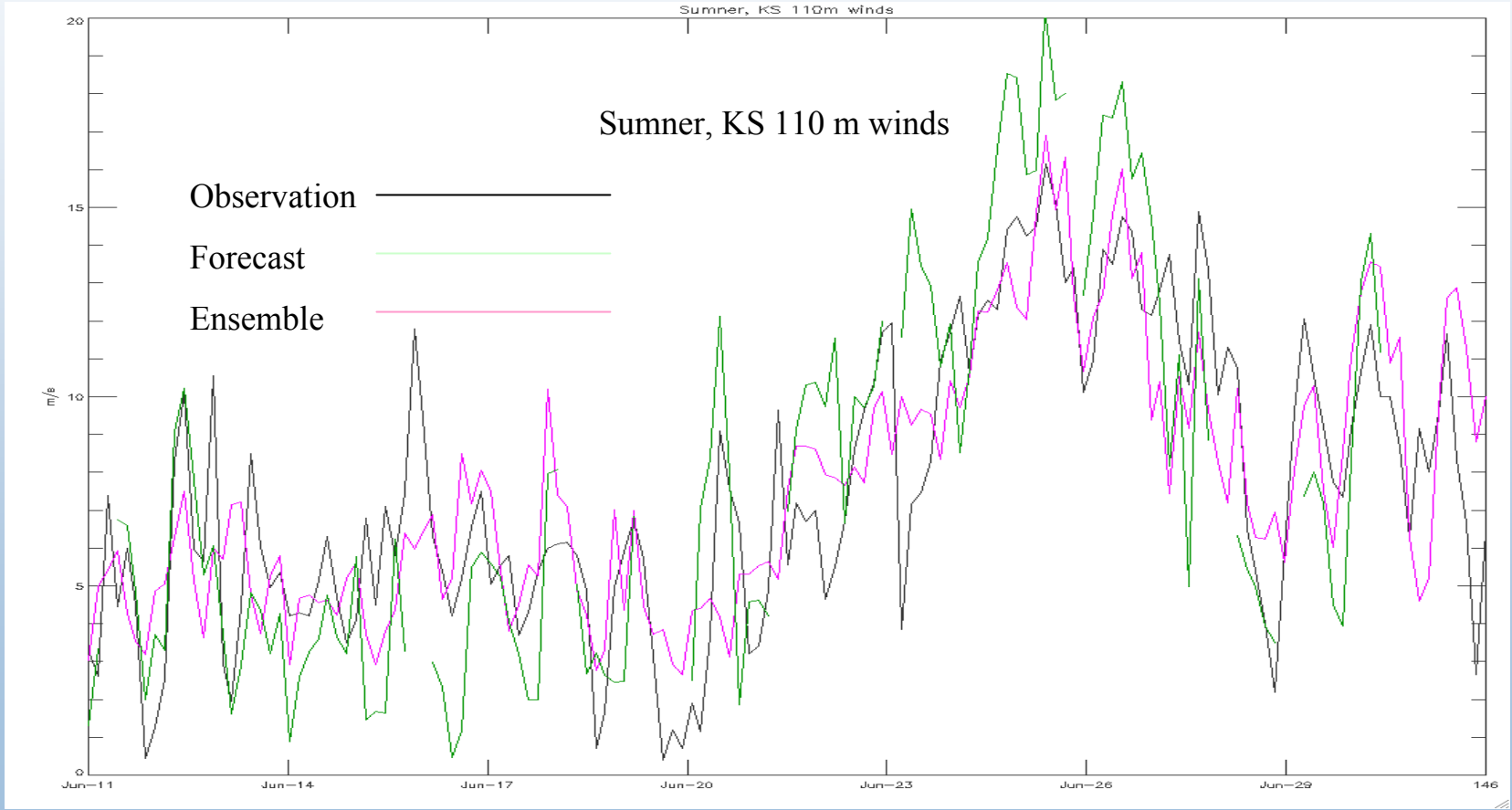
- Research in Europe (EU programs) in early 1990s
- 1997-98 NREL/private industry interviews with utility staff
- 1998- Establishment of Inter-Agency Agreement with NOAA/Forecast Systems Laboratory (FSL)
- DOE “seed” funds to TrueWind Solutions for development of their wind energy forecasting system
- NREL hosted first IEA technical workshop under Annex XI in 2001 and participated in 02 and 04 Symposiums
- Technical oversight of EPRI/CEC Texas-California forecasting project
- In-house statistical forecasting study using data from U.S. wind farms

Current U.S. Forecasting Activities

- Private industry providing forecasts to wind farm clients
  - Research by individual firms to upgrade their products
- Special projects designed to develop and test advanced forecast systems/techniques
  - CEC/EPRI CaISO forecasting project
- FSL forecasting research
  - Testing general accuracy of Rapid Update Cycle
  - Probabilistic wind forecasts (ensemble method)
  - Forecasting of low-level jet

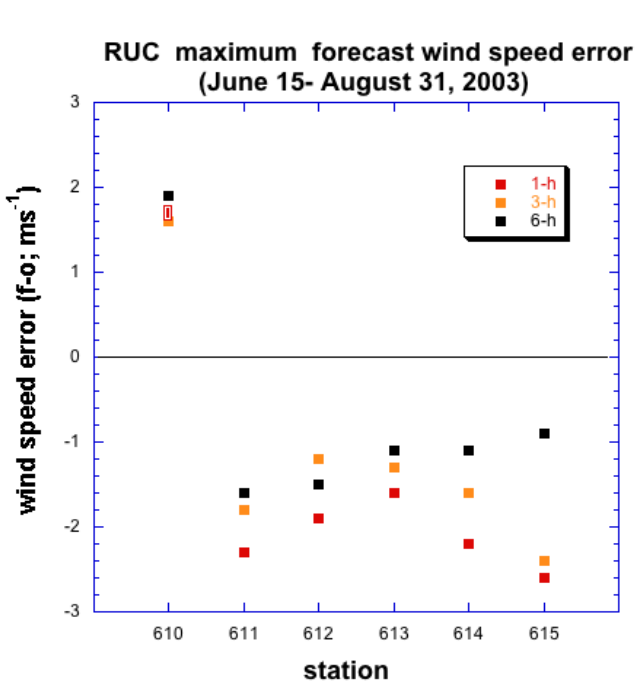
Ensemble Wind Forecasts

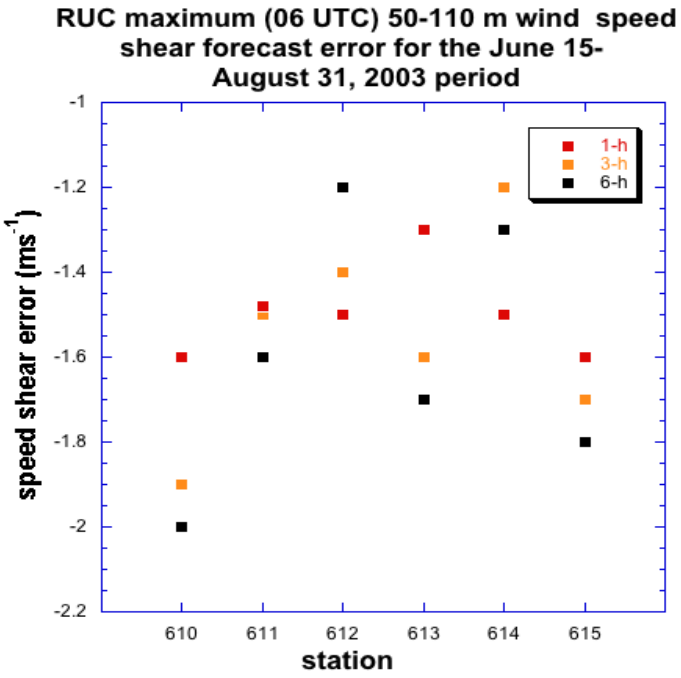
- Uses forecasts with common valid times to produce time-lagged ensemble forecast.
- 'Moving average' exponential decay used to combine forecasts.
- Bias correction applied to improve forecast quality.



LLJ preliminary results

- 6 towers in Kansas
  - Measurements at 50-m, 80-m, and 110-m levels.
- Study period June – August 2003





FY 05 Role of NREL

- Budget- $50K in-house, $150K for FSL work
- NREL contributions
  - Viewed as a source of unbiased expertise
    - On review panel for CaISO forecasting project
  - Can represent U.S. forecasting interests in absence of private industry
    - 2nd IEA Symposium in Denmark (Jun 04)
    - Preparation for 3rd Symposium to be held in U.S.
  - Liaison with FSL staff for guidance of forecasting research
    - Help FSL interpret results and plan follow on activities

Future Forecasting Work

- Aggregate and/or regional forecasts
- Probability forecasts
  - Advanced ensemble techniques
- Special feature forecasting
  - Low-level jet
- Event based forecasts

Tall Tower Analysis

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Major Issues

- Problem- Measurement data from hub-height levels of advanced turbines (100 m +) are rare
  - Creates large uncertainty for wind shear estimates
  - Unsure of how upper boundary layer features (ex. low-level jet) affect distribution of wind resource
  - Hinders/stops validation of meso-scale model output for these levels
  - Obstacle to turbulence characterization through blade swept area
- Opportunity- Existing tall communication towers and remote sensing instruments can provide needed data but……

Obstacles to Tall Tower Measurements

- "Good tall towers are hard to find!"
  - Leasing concerns
    - Competition from other potential users
    - Cost
  - Instrumentation issues
    - Pre-existing equipment
    - Tower shadow
  - Legal issues
- Remote sensing systems (Sodar)
  - Needs oversight
    - Noise
    - Weather (snow, humidity)

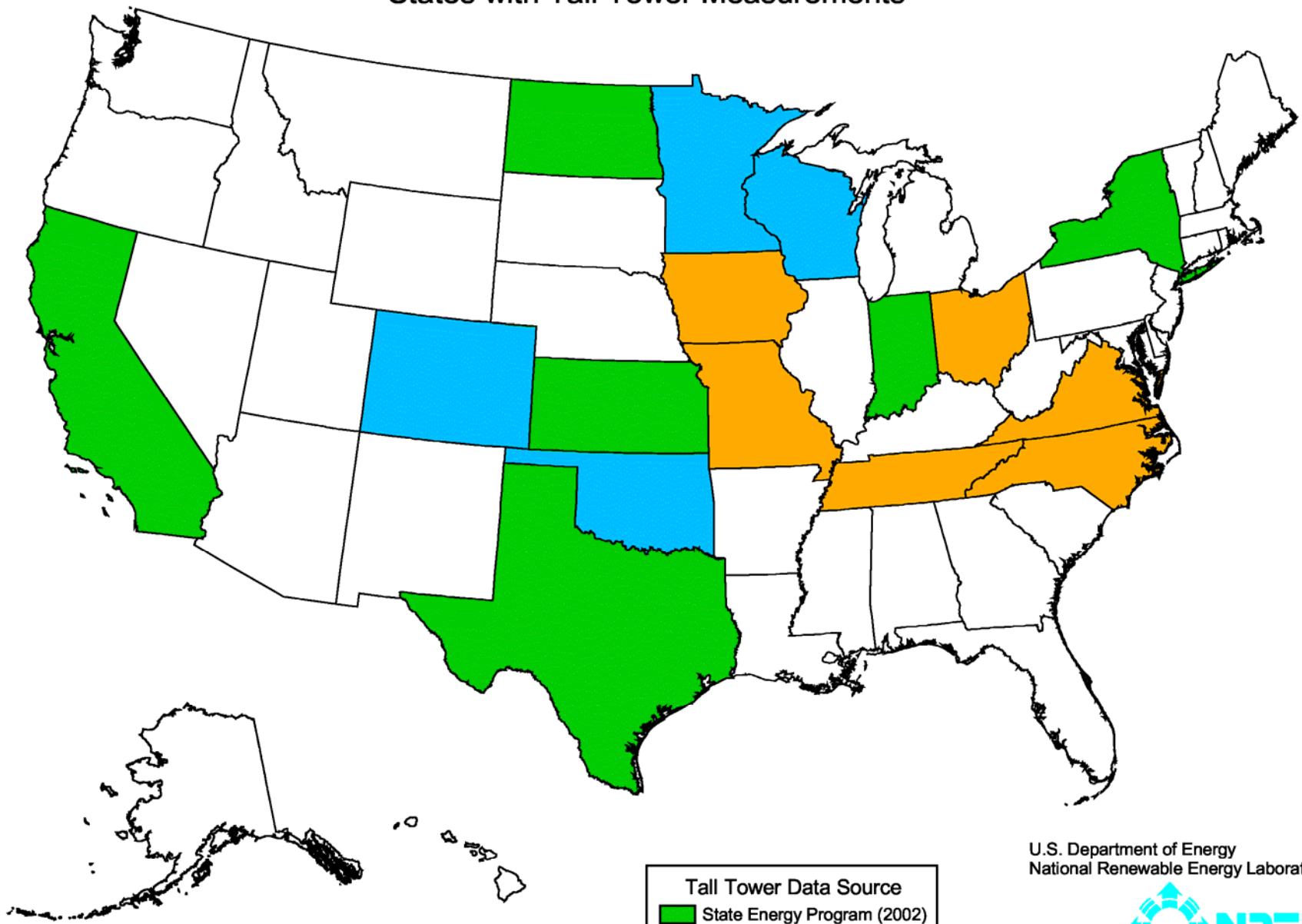
Past Tall Tower Work

- A few tall tower measurements made in Europe for "European Wind Atlas" (1980s)
- Mid to late 1990s saw a renewed interest in instrumenting tall towers and planning Sodar measurements
- Tall tower data identified as critical by industry at May 2001 U.S. Atlas Workshop held at NREL
- DOE State Energy Program (SEP) solicitations for tall tower measurements in 2002 and 2004
  - Supports 1 year of measurements

Current Tall Tower Activities

- Private industry and government Sodar studies being used for:
  - Comparison with tower measurements
  - Evaluation of specific proposed wind farm sites
- Tall tower measurements proceeding under SEP programs for 2002 and 2004
  - NREL provides technical support for states when requested
  - 12 states
  - Around 40 tall towers established by 02 and 04 programs
- Tall tower initiatives supported by state governments
  - Oklahoma
  - New Mexico

States with Tall Tower Measurements



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Sample Tall Tower Wind Data Inventory

State	Number of Towers	Heights	Months of Data	Period of Record	Program
California	1	110m	3	2004	DOE/SEP
Colorado	1**	113m	24	2001-2003	Other
Illinois	5**	114m, 90m, 76m	24	1990-1991	Other
Indiana	5	99m, 90m	9	2004	DOE/SEP
Kansas	6	110m	14	2003-2004	DOE/SEP
Minnesota	27	70m to 90m (120m*)	Up to 110	1990s-2004	State
New York	2	110m, 120m	3 to 14	2003-2004	DOE/SEP
North Dakota	3	TBD	TBD	TBD	DOE/SEP
Oklahoma	1	100m	15	2002-2003	State
Texas	2	100m	15	2003-2004	DOE/SEP
Wisconsin	1	123m	28	1999-2002	DOE,State,EPRI

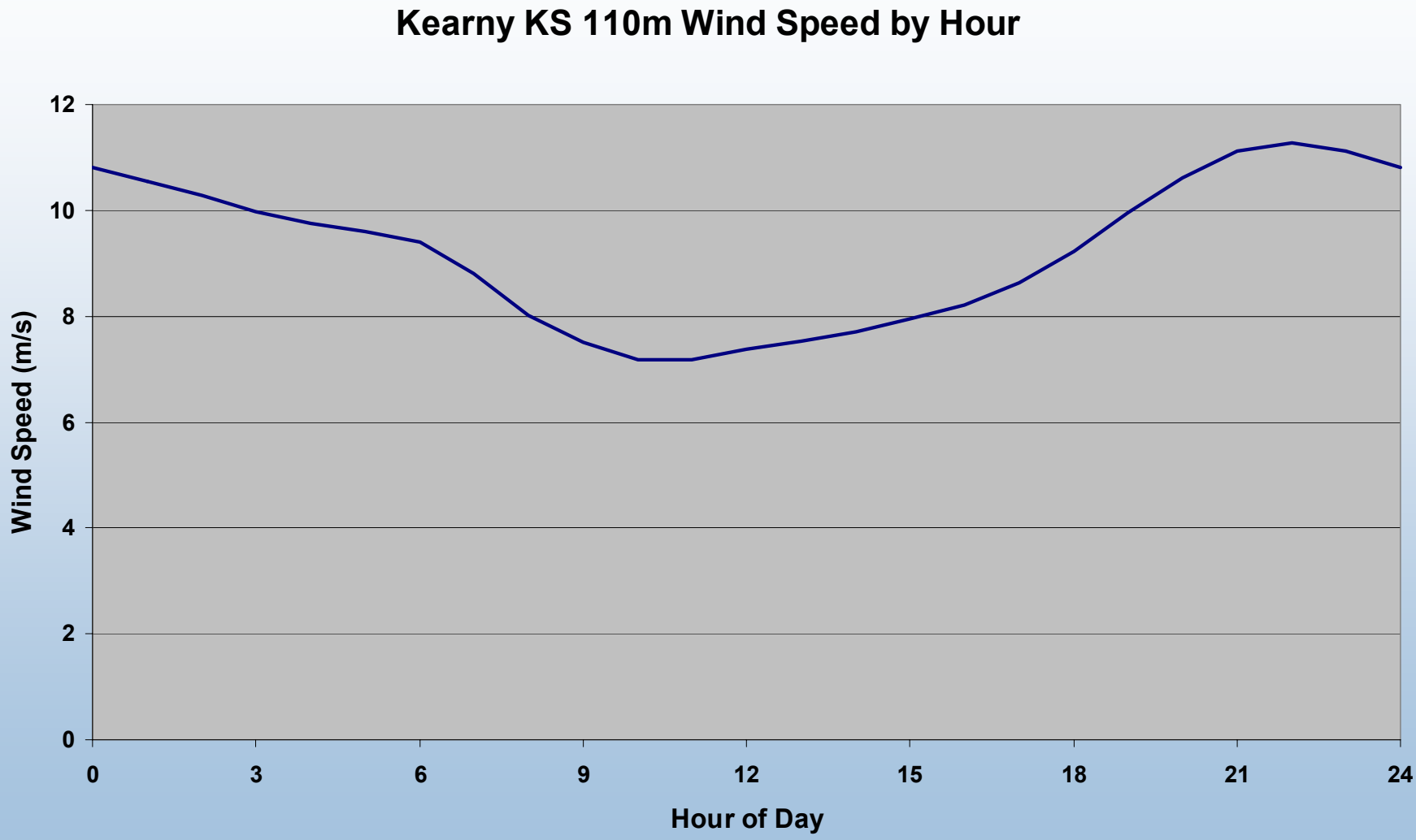
*1 week of data, **Proprietary data

Tall Tower Data Dissemination

- SEP- State has role during course of SEP funding
- Some states do have plans to put data on web-sites but…
  - Unclear how long these web sites will be maintained after measurements end
- Questions to be resolved
  - Should NREL be responsible for
    - Establishing a tall tower data base (common format)
    - Providing access to all non-proprietary data

FY 05 NREL Activities

- Budget- $110K in-house
- Measurement data from tall towers
  - Process data and perform quality assurance
  - Provide technical support when requested
- Comprehensive analysis of tall tower data
  - Sufficient data from 02 SEP to start analysis
  - Results from analysis can be used by several parties
    - Wind shear estimates by consultants and developers
    - Validation of 100 m maps or other resource visualization
    - Time series and profiles for grid integration
- Examination of remote sensing data sets
  - Wind profilers


Kearny KS 110m Wind Speed by Hour
Wind Speed (m/s)
0
2
4
6
8
10
12
0
3
6
9
12
15
18
21
24
Hour of Day

Future Tall Tower Work

- Because of difficulty in instrumenting tall communication towers
  - Tall tower measurements will not disappear but will be augmented by remote sensing network
- Program to evaluate Sodar (perhaps Lidar) accuracy
- Need to establish measurement network to obtain data from a wide variety of U.S. wind climate areas
- Develop resource maps or visualization tools of wind resource at turbine hub-heights

Offshore Mapping and Assessment

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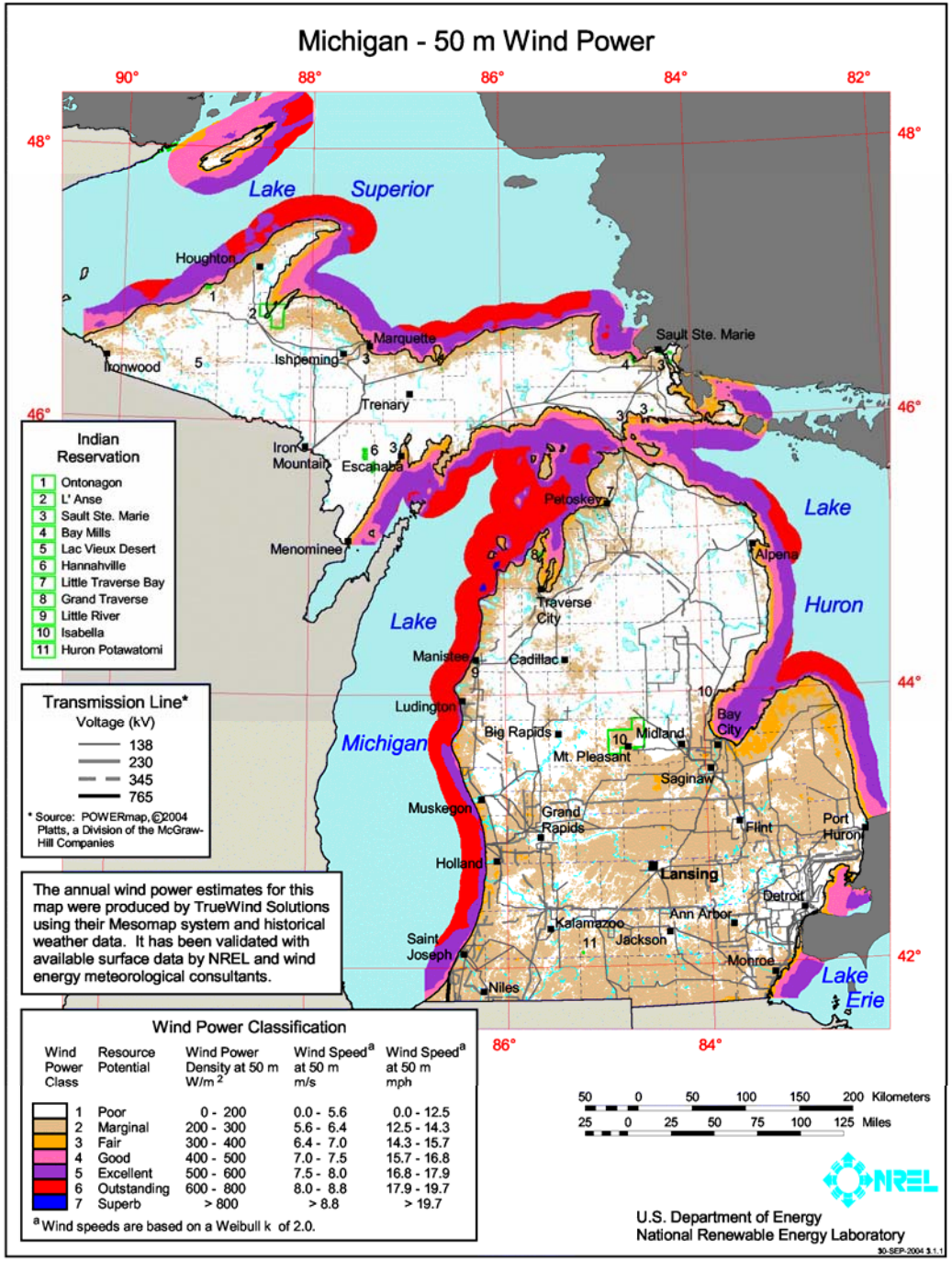
Major Issues

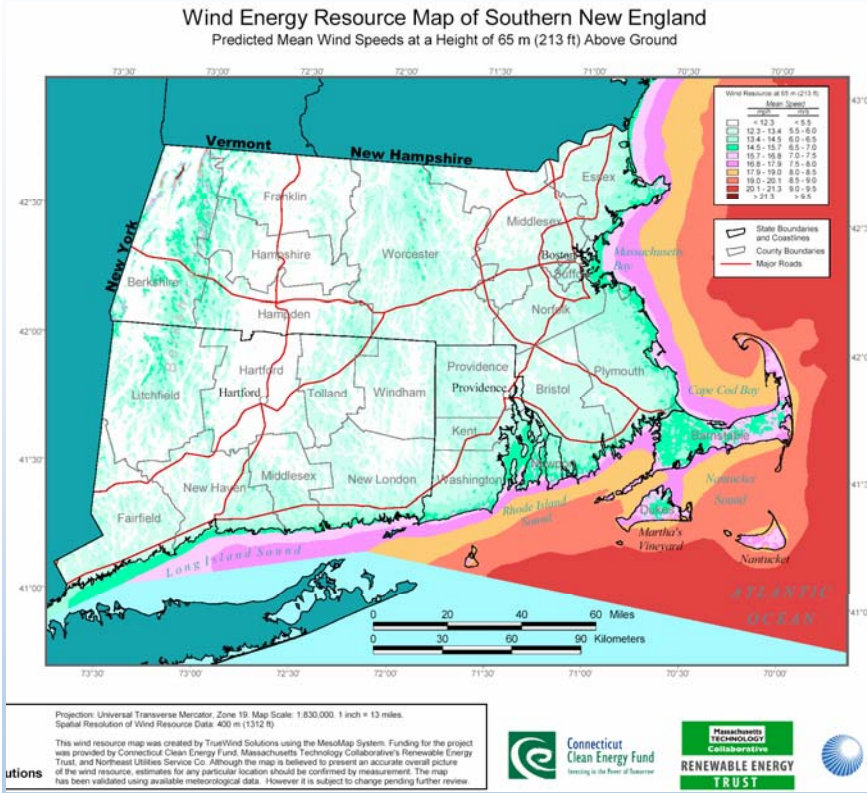
- Problem
  - The distribution of the wind resource in U.S. territorial waters (out to 100 nm) is much less known than the onshore resource
  - Methodology to convert offshore resource to electric potential needs to be established
- Opportunity
  - The development of meso-scale resource mapping offers chance to close gap in offshore knowledge
  - Offshore GIS data sets available for use in producing wind electric potential methodology

Past Offshore Mapping Work

- All recent offshore wind resource maps have completed by AWS Truewind as part of onshore mapping projects
  - Maps extend only 10s of km from shoreline
- Areas mapped
  - Atlantic- Maine through North Carolina
  - Pacific- Washington through California
  - Great Lakes- Parts of Lakes Erie, Huron, Michigan, and Superior
    - Part of Michigan state mapping project

Southern New England Wind Speed Map





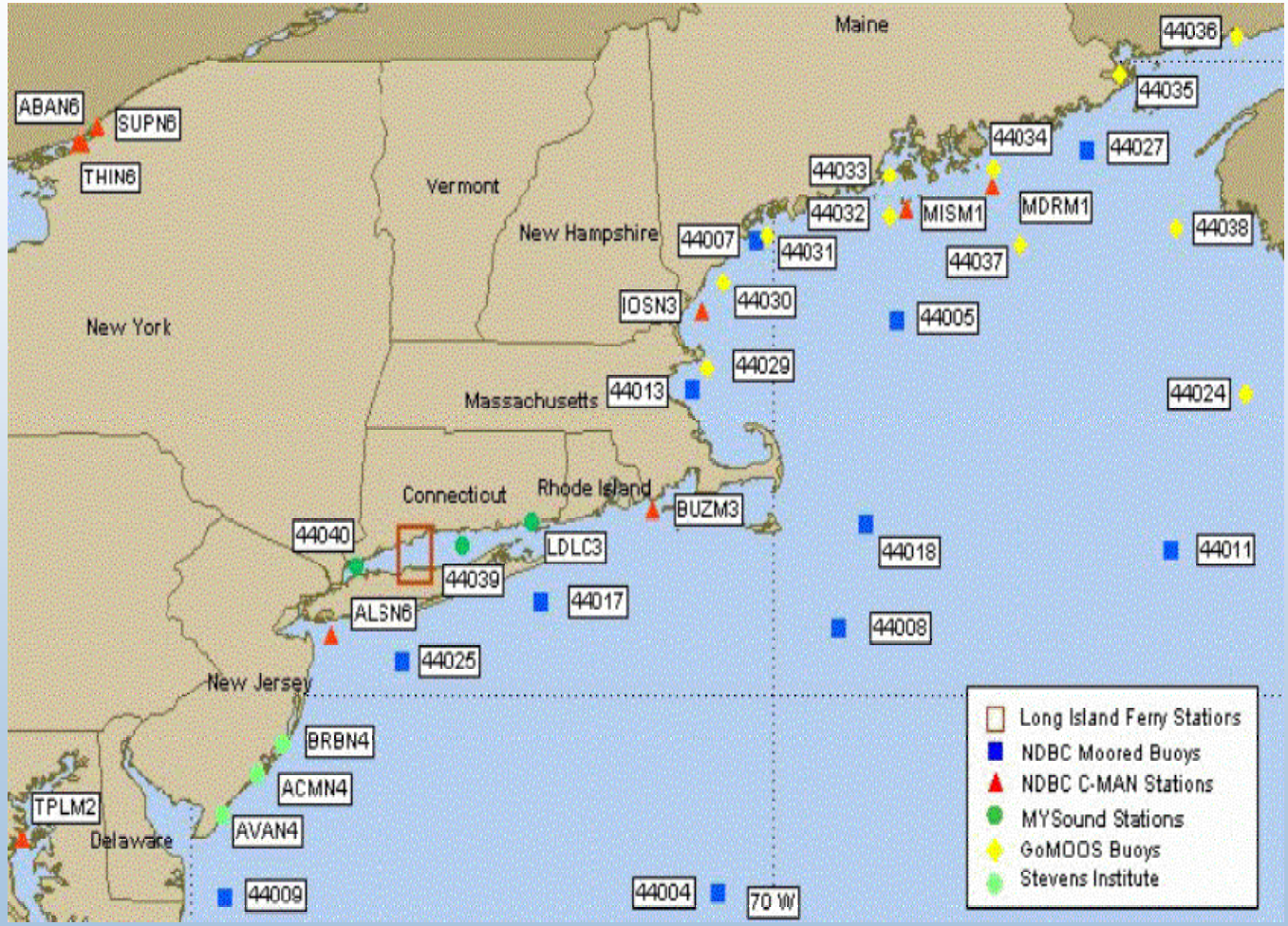
Recent Validation and Analysis Work

- Validated AWS Truewind offshore resource map from Maine through New Jersey
  - Used buoys, automated stations and ocean wind data derived from satellite measurements for validation
  - Resource pattern generally accurately depicted
    - Largest uncertainty is the gradient of resource near the coast
- Reached agreement to receive wind and water data from Cape Wind Tower
  - Have data from April 2003 through October 2004
  - Preliminary analysis of data of April 2003 to April 2004
    - No big surprises but some interesting characteristics

Offshore Assessment Barriers

- Barriers
  - Lack of validation data at turbine hub-heights (100 m+)
    - Buoy and satellite data are valid at low levels (5 m to 10 m) above ocean surface
    - Data from taller (20 m to 60 m) anemometers on automated stations are available but are widely scattered
    - Measured data tends to be clustered within 50 nm of coast
  - Marine boundary layer not well understood
    - Wind shear profiles
    - Air/water temperature differences
    - Effect of ocean currents on boundary layer processes

Map of Northeastern U.S. Buoys and Automated Stations



Preparatory Work for Wind Electric Potential Calculations

- Obtained offshore data sets (GIS format) that could be useful for determining exclusion criteria
  - Navigation charts
  - Bathymetry
  - Marine life habitat
  - Protected areas

Offshore GIS Data

Data Types and Sources

- MMS Active Lease Areas and Offshore Sand Sources - NOAA and MMS
- Military Danger Zones and Restricted Areas - NOAA
- Shellfish Areas - NOAA and MMS
- Coral Reefs - NOAA
- National Estuary Research Reserves - NOAA
- National Marine Sanctuaries - NOAA
- National Parks and Seashores - NOAA

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FY 05 NREL Activities

- Budget- $400K in-house $75K for mapping subcontract(s)
- Award subcontract(s) to map key regions
  - Exact regions not yet chosen
    - Amount of available validation data will be an important factor in choosing region(s)
- Validation and analysis tasks
  - Analysis of Cape Wind data
  - Validation of existing AWS Truewind maps and/or new meso-scale offshore maps
  - Search for new data sets that can aid offshore assessment
    - Doppler Radar winds
- Develop wind potential methodology

Future Work

- Mapping key regions
  - Recommend validation efforts concentrate on areas where the meso-scale model predicts gradients of resource
- State Energy Program for offshore towers
- Establish remote sensing measurement program for far offshore regions
  - Towers too difficult and expensive to build, operate and maintain
  - Need advanced remote sensing technology (ex. Sodar and Lidar) for high quality data
- Use numerical models to fill in data gaps
  - Support development of marine boundary layer modeling
- Establish wind electric potential methodology
  - Input from a variety of stakeholders